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An investigation into a proposal for a simplified television field synchronising signal

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THE BRITISH BROADCASTING CORPORATION

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AN INVESTIGATION INTO A PROPOSAL FOR A SIMPLIFIED TELEVISION FIELD SYNCHRONISING SIGNAL

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Summary

This report concerns a proposal which relates to a simplification of the 625/50 television field synchronisation signal; the object of the proposal is to reduce the duration of the synchronisation signal so as to leave more time in the field blanking interval for the transmission of data, test signals etc. The work described in this report was originally aimed at measuring the resistance to interference of the existing field synchronising signal and to use these measurements as a basis for assessing the suitability of proposed new forms of field synchronising signal. However, resistance to interference was found to be substantially unaffected when using the proposed form of synchronising signal, but examination of the effects of using the proposed form of synchronising signal on the synchronisation and interlace of domestic television receivers led to further investigations. It was found that a small but significant number of receviers suffered impairment of interlace when operating on the proposed signal.

Issued under the authority of

Head of Research Department

Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION

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1. Introduction

1.1. Outline of the scope of the work

The Synchronisation-signal Sub-group of EBU Technical Working Party M was formed as a result of a suggestion from RAI[1] to consider ways of simplifying the 625/50 television field synchronisation signal.* It was thought that the existing signal was unnecessarily long and occupied time that could be more usefully utilised for the transmission of data and other signals. The detailed terms of reference of the Sub-group are given elsewhere[2] but briefly are as follows:–

1. To determine the resistance to noise of the standard synchronisation system.** Any new system should be at least as resistant to interference as the existing one.
2. To determine the most suitable form of new field synchronising signal and to confirm this suitability by experiment.

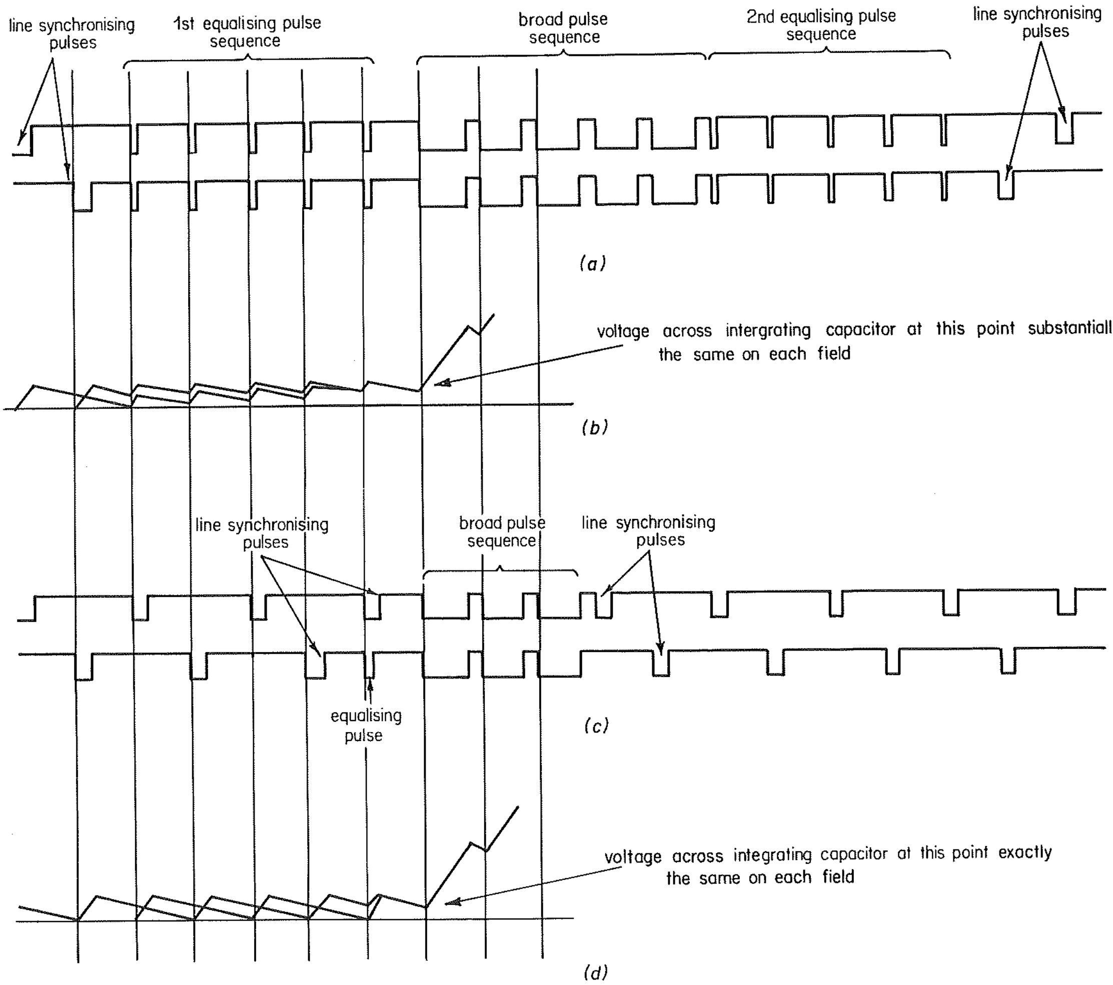
line synchronising pulses
1st equalising pulse sequence
broad pulse sequence
2nd equalising pulse sequence
line synchronising pulses
(a)
voltage across intergrating capacitor at this point substantially the same on each field
(b)
line synchronising pulses
broad pulse sequence
line synchronising pulses
equalising pulse
(c)
voltage across integrating capacitor at this point exactly the same on each field
(d)

Fig. 1 - (a) Standard Field Synchronising Waveform (b) Voltage across capacitor of R-C integrator with standard waveform (c) New field synchronising waveform proposed by U.K. (d) Voltage across capacitor of R-C integrator with proposed waveform

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* The synchronising signal sub-group of EBU technical working party M, has, since the final drafting of this report, been disbanded. It is intended that the work carried out should now form the basis of a direct contribution to the CCIR.

** System here means the transmitted field synchronising signal and its use to synchronise domestic television receivers.

The work would involve co-operation with receiver manufacturers and other broadcasters and would result ultimately in an EBU contribution to the CCIR.

A proposal made to the Sub-group by the UK was based upon a UK proposal[3] made to the CCIR in 1965. The work described in this report was an investigation into the performance of the existing system (as defined in clause 1 above), together with assessment of the suitability of the new UK proposal.

As will be seen, immunity of field synchronisation to interference proved to be adequate in both cases and was not a problem. However, the study of the synchronsiation and interlace of receivers occupied a substantial proportion of the work described in this report.

In order to carry out the tests as outlined above, 21 television receivers (10 colour and 11 monochrome) were borrowed from BREMA*. The receivers were considered by BREMA to represent a cross-section of the circuit designs currently in use in the U.K. The anoynmity of the receiver types and manufacturers has been preserved in this report by assigning to each receiver a code letter.

1.2. Outline of the UK proposal

The new UK proposal is defined more fully elsewhere[4,5] but a description is given below which describes its most important features.

Fig. 1(a) illustrates the field synchronising waveforms on alternate fields as they are transmitted at present. There are five broad pulses, and two groups of five equalising pulses, one before and one after the broad-pulse sequence. Fig. 1(c) illustrates the UK proposal for a modified field synchronising signal which was intended to be fully compatible with existing receivers. In this proposal, the number of broad pulses is reduced to three, and there is only one "pre" equalising pulse** every other field. The proposal also effectively advances the broad-pulse sequence by two lines in order to allow all the time released by the proposal to be available without interruption after the broad-pulse sequence. However, for purposes of comparison, in Fig. 1 the existing and proposed systems are illustrated with the beginnings of the broad-pulse sequences lined up. Fig. 1(b) and (d) will be referred to in Appendix B.

One incidental advantage of the UK proposal (carried over from the original[3]) lies in the fact that the start of a line synchronising interval as not defined by the equalising pulse; the equalising pulse used occurs at the mid point of a line synchronising interval. This means that the transmission of Sound-in-Syncs[6] (which requires a continuous stream of line synchronising pulses with duration not less than 4·7μs) would be possible without modifying the waveform in any way. This advantage is not shared by the standard waveform which requires extra processing to widen some of the equalising pulses when Sound-in-Syncs is used.

2. Measurement of the resistance of different field synchronising signals to various types of interference

2.1. Description of apparatus

In order to study the effects of various forms of interference on a number of receivers simultaneously, using a number of different synchronising waveforms, the apparatus shown in Fig. 2(a) was assembled.

2.1.1. Waveform Generator

The generator of the non-standard synchronising signal was capable of being switched to provide a number of different waveforms e.g. the number of broad pulses could be switched from 0 to 1,2,3,4 or 5; the number of post and pre equalising pulses could also be changed and their durations varied. Finally, a change-over switch enabled the system to be switched from 'non-standard' to 'standard' synchronising waveform at any time. Care was taken to ensure that the rise-times of the non-standard synchronising waveform were identical to those of the standard waveform and that the relative timings of video and synchronising signals were accurately maintained.

2.1.2. Impulsive-interference generators

Four generators of impulsive interference were used in the tests. The first was designed to simulate impulsive noise interference without the use of sparking contacts. The apparatus comprised a white-noise generator whose output spectrum was confined, by a band-pass filter, to the u.h.f. band. The impulsive noise simulation was achieved by gating the output of this noise source, as illustrated in Fig. 2(b), into bursts having adjustable duration and repetition frequency. Generally, the repetition frequency was maintained at approximately 100 Hz so as to simulate the making and breaking of electrical contacts twice every cycle of the mains supply. The advantage of this type of generator over the mechanical 'sparking-contact' lies in the consistency and repeatability of the relevant parameters of the impulses, e.g. their rise-times, amplitude, duration and frequency of repetition. The appearance on the television picture of the gated noise interference is shown in photograph Fig. 3 (a).

The second impulsive interference generator consisted of a mercury-wetted-contact impulse-generator of commercial manufacture. The repetition frequency of the interference pulses from this generator could be varied.

The third generator was an automobile ignition system producing a spark discharge across the points of a standard sparking-plug.

The fourth consisted of a pair of contacts arranged to produce an arc similar to that caused by the opening contacts of a domestic thermostat, or similar device. The effect of this type of interference is shown in the photograph Fig. 3(b) and is seen as thin horizontal rows of white dots.

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*British Radio and Electrical Manufacturers Association.

**Throughout this report the terms "pre" equalising pulse and "post" equalising pulse will be used. The prefixes 'pre' and 'post' will be understood as referring to the groups of equalising pulses before and after the broad-pulse sequence respectively.

Unlike the gated white noise generator, the outputs from the mechanical-contact devises were somewhat unpredictable and the levels of interference varied considerably with time, necessitating frequent monitoring.

2.1.3. R.F. Systems

As shown in Fig. 2(a), two u.h.f. signal generators were used, one to provide the carrier modulated by the vision waveform and the other to introduce a sound signal at the correct relative level and frequency appropriate to the vision channel in use; the sound carrier was provided in order to simulate as closely as possible the signal conditions obtained at the input of a receiver under normal conditions.

Double-sideband vision signals were provided by the RF modulator and care was taken to ensure that each receiver was tuned to the correct side-band.

An accurately calibrated receiver was used to monitor the strength of the signals distributed to the domestic receivers; this also enabled the distribution system itself to be checked for variations in signal level from receiver to receiver.

2.2. Test procedure

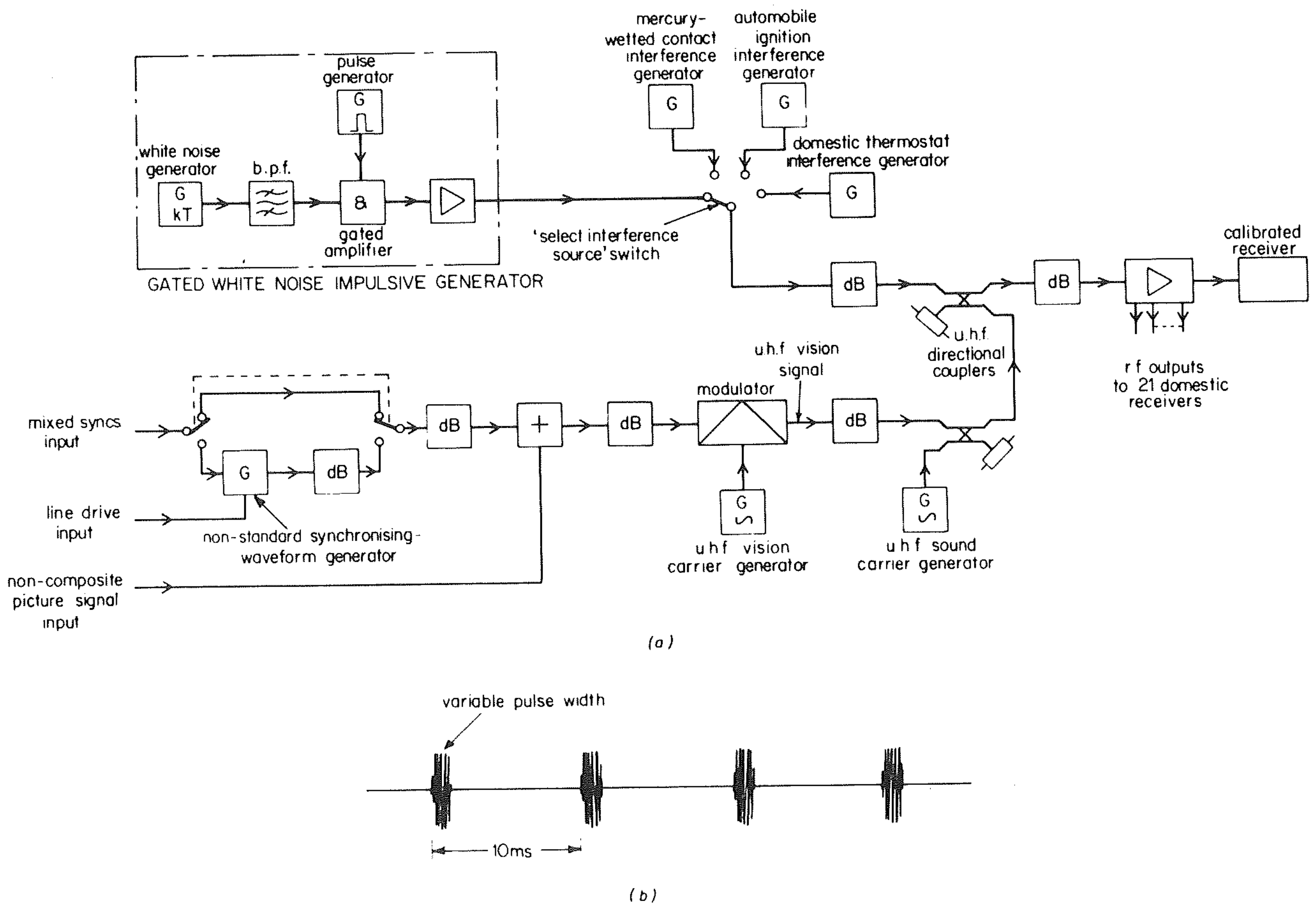
For each test all the receivers were adjusted initially to display a satisfactory picture when fed with a standard u.h.f. vision signal at approximately 550 MHz; this frequency was chosen in order to avoid interference from broadcast signals in the area. The vertical and horizontal time-base controls were not adjusted at this stage; later investigation showed that these control settings were not critical and receivers became more susceptible to interference only when they were on the point of losing synchronism due to the controls being 'on edge'.

With the receivers set up as described above, the signal level was first adjusted to give substantially noise-free pictures, i.e. at a level approximately 72 dB above 1μV.

The results of the following tests are given later in Section 3 of this report.

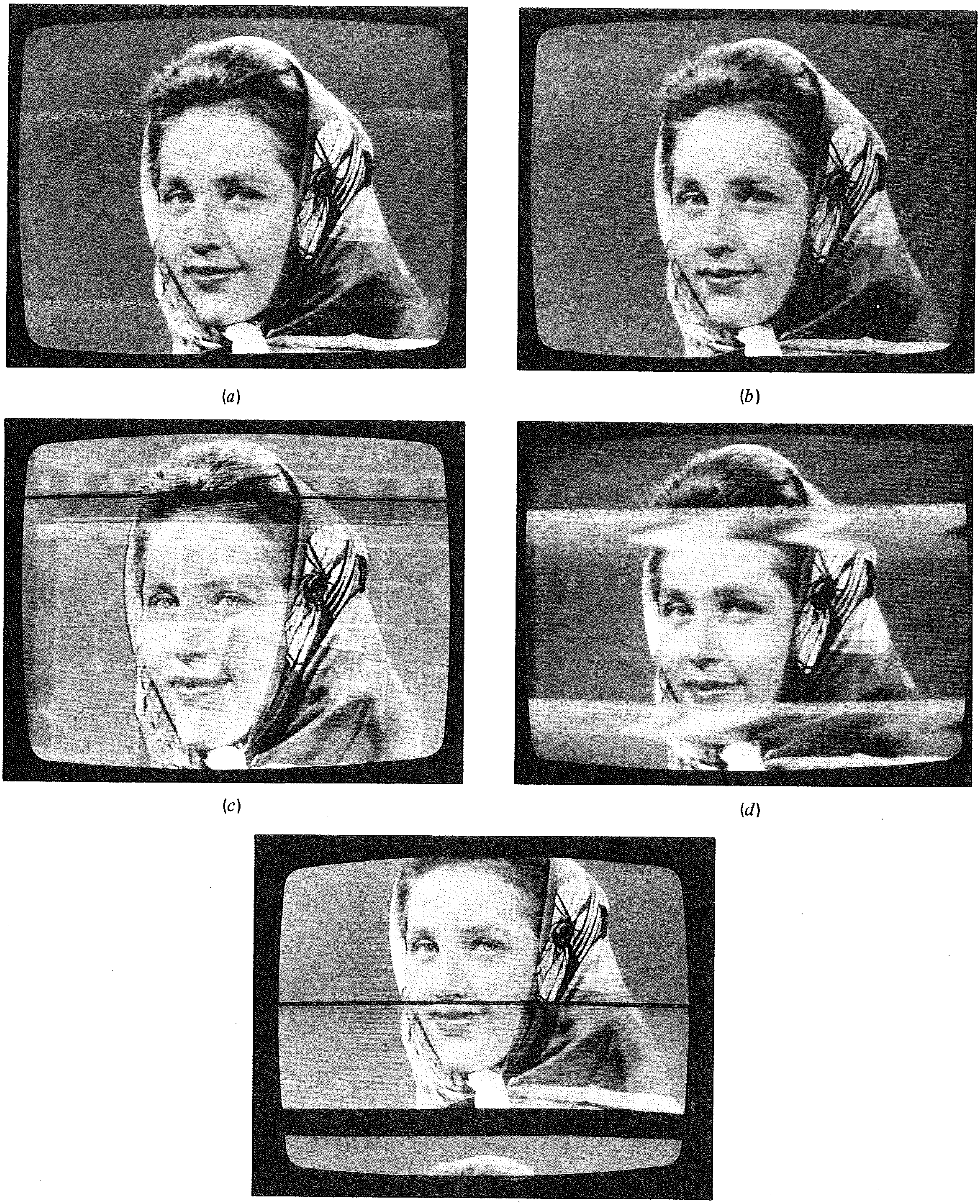
2.2.1. Test 1 Impulsive-noise interference, simulated by bursts of random noise

The gated white-noise generator was used first and the gating pulse generator was adjusted to provide pulses with



mercury-wetted contact interference generator
automobile ignition interference generator
pulse generator
G
white noise generator
b.p.f.
G
kT
&
gated amplifier
domestic thermostat interference generator
G
'select interference source' switch
GATED WHITE NOISE IMPULSIVE GENERATOR
calibrated receiver
dB
dB
u.h.f directional couplers
u.h.f vision signal
modulator
r f outputs to 21 domestic receivers
mixed syncs input
dB
+
dB
dB
G
dB
line drive input
non-standard synchronising-waveform generator
u h f vision carrier generator
u h f sound carrier generator
non-composite picture signal input
(a)
variable pulse width
10ms
(b)

Fig. 2 - (a) Block diagram of experimental set up used for all the measurements (b) Typical RF waveform of gated white noise generator



(*a*) (*b*) (*c*) (*d*) (*e*)

Fig. 3 - Photographs illustrating types of interference

(*a*) Gated noise (*b*) Thermostat contact simulation (*c*) Co-channel (*d*) Receiver whose line scan circuits were seriously disturbed by interference (*e*) Receiver locking onto severe interference a repetition frequency of approximately 100 Hz and a duration of about 32 μS as a convenient minimum.

Tests were carried out at three vision carrier levels, namely 72 dB, 52 dB and 42 dB above 1μV. This represented a progression from relatively strong signals to others which were seriously impaired by receiver-generated noise; the aim was to investigate the dependence on signal level of susceptibility to interference. At each level, the strength of the interfering signal was slowly raised until perceptible vertical jitter of the picture was visible on at least one of the receivers; the make and type number of the first receiver(s) to be affected was noted. The level of the interfering signal was then progressively increased until all the receivers were affected, and the make and type number of the last to be affected was also noted. The above experiment was repeated using both the standard field synchronising waveform and the one proposed by the UK.

This procedure was followed, in further tests, with progressively increasing pulse-duration up to 20 ms, the pulse repetition frequency being maintained at approximately 100 Hz.

2.2.2. Test 2. Impulsive-noise interference, generated by contact or a spark gap

The previous experiment was repeated using, in turn, the other three forms of impulsive noise generators. In some cases an extremely high noise level, with respect to that of the signal, was required to affect field synchronisation, and for this reason it was sometimes necessary to lower the signal level in order to avoid over-loading the system. For these reasons results were only obtained at one signal elvel for each of the noise sources.

During both Tests 1 and 2, a check was made at a vision carrier frequency of 800 MHz in order to conform the consistency of the results at a frequency in the u.h.f. band, relatively remote from that used for the majority of the tests (550 MHz).

2.2.3. Test 3. Random noise interference

The next series of experiments was concerned with random fluctuation noise as a source of interference, thus simulating the conditions which might be encountered when a large amount of aerial pre-amplifier gain is used in areas of poor signal strength.

The white-noise generator was used un-gated and once again the level of the interference was slowly increased in steps and the first and last receivers to be affected were noted. At each step in the tests, the field synchronising waveform was switched between the existing and proposed waveforms and differences in received performance, if any, were noted. The experiment was then repeated with vision signal-strength progressively reduced until, without added noise, one or more receivers, began to lose field synchronisation. Noise was then added until the last receiver lost field synchronisation.

2.2.4. Test 4. C.W. Interference

Experiments were next conducted in order to examine field synchronisation of the receivers in the presence of an interfering c.w. signal. The criterion for synchronisation was, as in the previous tests, that perceptible vertical jitter became visible.

In the first part of this test a c.w. interfering signal was introduced into the r.f. distribution network from a u.h.f. signal generator providing an unmodulated carrier whose frequency was adjusted to be offset from that of the vision carrier by roughly one-and-a-half times line-frequency; this frequency was found to be one of the most damaging in terms of interference with receiver synchronisation.* The test was then repeated with the interfering signal readjusted to give a beat at a less damaging frequency, approximately equal to that of the PAL subcarrier.

In the second part of this test, co-channel interference was simulated using the BBC–2 u.h.f. vision signal as the interfering signal, the frequency of the locally generated vision carrier being again adjusted to the required offset of one-and-a-half times line frequency; see photograph Fig. 3(c). The field synchronisation of each receiver was again assessed using the present and the proposed field-synchronising signals, with varying levels of interference.

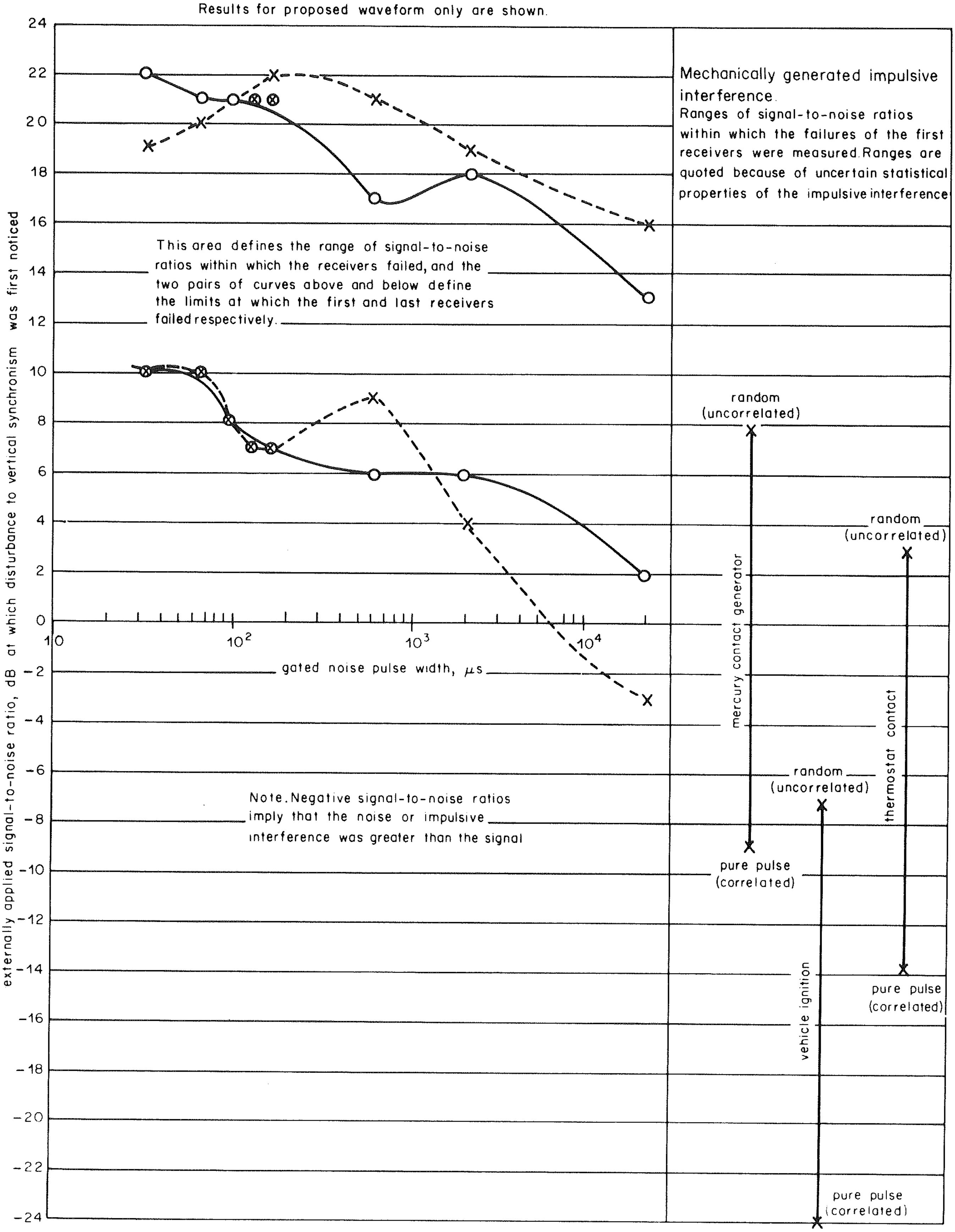
2.3. Noise Measurement Techniques

2.3.1. The Measurement of Impulsive Interference Levels

The measurement of impulsive noise levels is not a straight-forward operation, since account has to be taken of the annoyance caused by a wide variety of sources having widely differing temporal and spectral characteristics. A number of methods exist by which a quantitative evaluation can be obtained of the characteristics of the interference. One approach favours the measurement of the peak noise levels. This would, perhaps, be applicable to certain impulsive sources, but one could not justify, for example, an attempt to measure the peak value of white noise, as this is so ill-defined. Another approach uses digital techniques, and attempts the evaluation of noise by counting the number of peaks per unit time which exceed a given voltage level[7].

Yet another approach, the use of the quasi-peak method, was used in these experiments. It was primarily designed to measure the annoyance caused to a.m. telephony by sources of impulsive interference. However, its use can be extended to television broadcasting where although the agreement between subjective annoyance and measured levels is less good, it is usually considered to be adequate. Quasi-peak measuring receivers are therefore widely accepted in the UK and abroad for general-purpose interference measurements up to 1000 MHz[8,9]. The measurements obtained from such a receiver are specified

*In practice the BBC uses carrier frequencies which are offset by five thirds of line-frequency and which would be less damaging than the one found in the tests.



Mechanically generated impulsive interference.

Ranges of signal-to-noise ratios within which the failures of the first receivers were measured. Ranges are quoted because of uncertain statistical properties of the impulsive interference

This area defines the range of signal-to-noise ratios within which the receivers failed, and the two pairs of curves above and below define the limits at which the first and last receivers failed respectively.

Note. Negative signal-to-noise ratios imply that the noise or impulsive interference was greater than the signal

Fig. 4 - Diagram summarising the results of the noise interference tests

O————O Signal level 72 dB above 1μV X– – – – – –X Signal level 42 dB above 1μV as 'the RMS voltage of a sine wave which would give the same reading as the interference source being measured'. The response of the receiver to repeated bursts of noise depends on certain defined time-constants in the receiver voltage indicator. The required relationship of response as a function of repetition frequency, together with other specified parameters may be found in British Standard No. 727[8,9]. A special receiver* conforming to this standard was obtained on loan for the purpose of these measurements.

2.3.2. The Spectral Characteristics of Noise

The bandwidth of the measuring receiver used was 120 kHz. In order to obtain measurements of signal-to-noise ratios affecting the television receivers, it was necessary to compensate for the difference in bandwidth between the measuring receiver and the television receivers, according to the kind of noise being considered.

Thermal noise has spectral components which are totally uncorrelated, and it is well known that the r.m.s. thermal noise voltage at the receiver output is proportional to the square root of the bandwidth of the receiver. Hence the adjustment of the results to compensate for the bandwidth of the television receivers in the case of thermal noise is based on that relationship.

In the case of interference consisting of 'ideal' pulses having a flat, correlated spectrum, the interfering voltage is proportional to the bandwidth and a linear correction factor is necessary in the adjustment of the results.

In general, mechanically produced impulses have spectral components which are partly random and partly correlated and the correction factor is impossible to define unless the characteristics of the noise source are known. This is not always possible, although some guidance can be obtained from the experience of those who have carried out detailed investigations into this field**. For example, the gated noise generator used in the experiments is clearly an uncorrelated source. Ignition interference, on the other hand, tends to be correlated, whilst commutator interference tends to be uncorrelated. The best that can be done when measuring noise sources of uncertain character is to quote the range within which the result must lie, and indicate the probable noise level of the source within that range.

3. Disscussion of results

3.1. Results for electronically generated noise

The results of tests 1,2, and 3 are summarised in Fig. 4.

The results for tests 1 and 3 are represented by the graphs, which are a plot of signal-to-noise ratio for loss of field synchronism, as a function of the noise pulse width (the results for continuous noise are thus represented on this graph as pulses having a duration of 20 ms). Four separate curves are plotted in two pairs. In each pair, the upper curve represents the failure of the first receiver, and the lower curve represents the failure of the last receiver, thus defining the region within which all the receivers failed.

The two pairs of curves represent the results for signal levels of 72 dB and 42 dB above μV and since little or no difference was seen when comparing the proposed and standard field synchronising signals, the curves are equally applicable to both waveforms. It may clearly be seen that there is a trend for the interference susceptibility of the field synchronising circuits to decrease as the noise pulse width increases. This seems to be associated with the a.g.c. action in the receiver; short bursts of interference will have little effect on the a.g.c. but will cause severe overloading during the interference bursts. If the bursts of interference occur during the broad pulse sequence it is quite conceivable that the field sync separation will be severly impaired through overloading. Continuous noise, on the other hand, will cause the a.g.c. to reduce the gain, and the susceptibility to interference will then depend on the noise immunity of the field sync separator in the presence of non-overloading signals plus noise.

Perhaps the most important conclusion to be drawn from the tests is that the use of the proposed waveform did not adversely affect the interference immunity of the receivers; all the interference tests carried out were consistent in this respect, irrespective of the nature of the interference. In the light of experiments conducted into other aspects of the performance of the proposed system, it was later concluded that the use of three broad pulses might be unsatisfactory for other reasons (this is discussed more fully under section 4), and so checks were made of the performance of a waveform using five rather than three broad pulses under the same conditions of interference. The results were in fact always identical to those obtained with the standard waveform.

3.2. Results for mechanically generated noise

The results obtained for the mechanically generated impulses will now be considered; these are displayed on the right hand side of Fig. 4. These were totally independent of the nature of the field synchronising signal, so only one result is presented for each form of interference. Having regard to the uncertain proportions of correlated and uncorrelated noise, ranges have been indicated within which the noise level lay at which one or more receivers were affected. Noise levels at which the least sensitive receivers were disturbed occurred were so high that severe brightness interference was already present, thus making the disturbance to field synchronisation of academic interest only.

It seems probable that the outputs from the thermostat and mercury-contact generators lay nearer to the random end of the range, whilst that from the vehicle-ignition generator was nearer the pure pulse end of the range. Hence it would appear that for impulsive inter-

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* Type Swartzbeck 1520A

** Assistance was obtained from E.R.A., Leatherhead ference of the make-break contact type, disturbance first occurs to vertical synchronisation at a signal-to-noise ratio of 8 dB. The vehicle ignition generator, probably because of the short duration and relative infrequency of its pulses was tolerated at high levels by the receivers.

3.3. Results for CW and co-channel interference

Fig. 5 illustrates the relative levels of cw and co-channel interference to cause loss of field synchronism. Results are quoted for cw and co-channel interference with an offset of one-and-a-half times line frequency (found by experiment to be one of the most damaging to field synchronisation). Also, for comparison, the ratios for cw with a non-critical offset (approximately colour sub-carrier frequency) are included. In the case of cw with an offset of one-and-a-half times line-frequency one receiver was impaired at the surprisingly high signal-to-interference ratio of 33 dB. This was higher than for any of the impulsive noise sources, but again there was little if any difference between the results for the standard and proposed field synchronising waveforms.

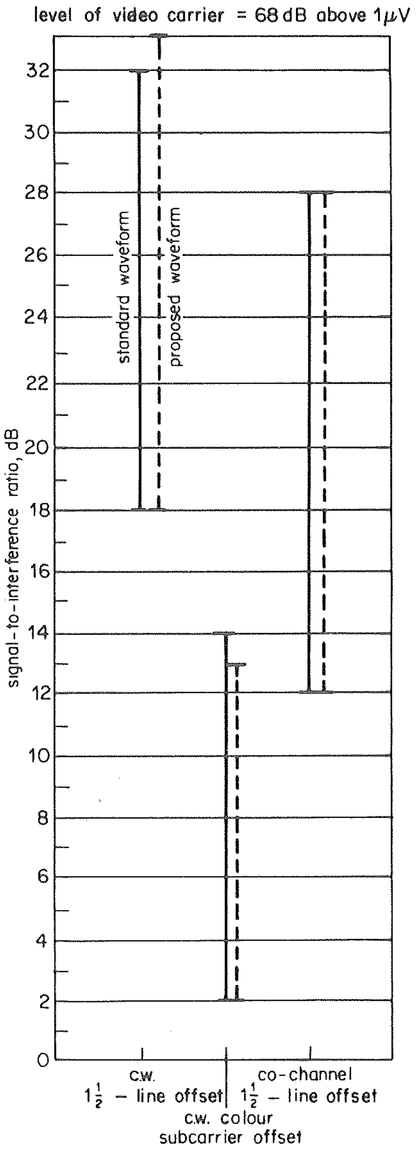

Fig. 5 - Diagram summarising the results of the c.w. and co-channel interference tests

During the tests on interference no single receiver was consistently the first to lose vertical synchronisation, neither was there a particular receiver which was always the last; however, there seemed to be two groups of receivers whose members appeared repeatedly among the first and last to be disturbed. These receivers are identified in a summary in Appendix A, which also lists certain performance characteristics of the receivers, not immediately relevant to the investigation, which were observed. For example, it seemed worth while recording the receivers whose line synchronising was more easily affected by interference.

4. Other aspects of the performance of the U.K. Proposal

Whilst the U.K. proposal was found to have resistance to interference which was essentially identical with that

RECEIVER IDENT LETTER	(Number of broad pulses with which field synchronisation was not obtainable) 0	1	2	3	4	5
A	X	X				
B	X	X	X	X	X	
C	X					
D	X					
E	X					
F	X	X				
G	X					
H	X					
I	X					
J	X					
K	X					
L	X	X	X	X	X	
M	X					
N	X	X				
O	X					
P	X					
Q	X					
R	X					
S	X					
T	X					
U	X					

Fig. 6 - State of field synchronisation of receivers as received from manufacturers

of the standard waveform, its other characteristics must also be satisfactory in other respects, and the opportunity was taken to investigate them more fully. This led to a greater understanding of how the present waveform is now being used, and to the conclusion that in some cases at least, it is not being used in the way generally assumed.

The following criteria were examined using the same 21 colour and black and white domestic television receivers:

(a) The dependence of field synchronisation on the number of broad pulses.

(b) The dependence of interlace upon the equalising pulses.

RECEIVER IDENT.	COMMENTS
A	*
B	*
C	**
D	***
E	***
F	****
G	*
H	***
I	**
J	**
K	*
L	*
M	***
N	*
O	***
P	***
Q	***
R	**
S	**
T	**
U	**

COMMENTS

*	Significant variation in range with the number of broad pulses (6 receivers)
**	No vertical hold control accessible (7 receivers)
***	Locking range independent of the number of broad pulses (7 receivers)
****	Slight variation in range with the number of broad pulses (1 receiver)

(figures in brackets denote the number of receivers affected in each case).

Fig. 7 - Effect of the number of broad pulses on the vertical synchronising range

4.1. Dependence of field synchronisation on the number of broad-pulses

Criterion (a) was initailly examined by varying the number of broad-pulses between 0 and 5, whilst leaving one pre equalising pulse. Fig. 6 summarises the results obtained when the receivers were tested in the condition in which they were delivered (i.e. without adjustment of the vertical hold control). Subsequently, it was found that all the receivers except one (receiver F) could be made to synchronise on a single broad-pulse by adjustment of the 'vertical-hold' control where necessary. Having established that all the receivers tested were capable of synchronising reliably on a signal containing three broad-pulses, an attempt was made to determine whether the range of the vertical-hold control for which the picture could be synchronised was a function of the number of broad-pulses in use and, if so, to what extent the range was so affected. It was possible to carry out tests on only about 66% of the receivers, since some did not have accessible vertical-hold controls. The results are summarised in Fig. 7. Of the receivers tested, approximately half showed significant variation in the range in which synchronisation was achieved with number of broad pulses.

It was decided to attempt to measure this variation quantitatively for receiver A, which seemed typical of those which showed variation in range of synchronisation. In order to do this, the vertical-hold control was calibrated for a given setting by noting the frequency at which the field-scan oscillator would free-run in the absence of a field synchronising signal. Thus, for a given number of broad pulses, the extremes of the range could be defined. The results are summarised in the graph Fig. 8. It is seen that there is a 25% reduction in locking range in changing from five to three broad-pulses. It was felt that this was sufficiently serious to call into doubt the wisdom of proposing a system with three broad-pulses, if complete compatibility were to be required. It was decided, therefore, that further tests should include a waveform which had five broad-pulses, but which was otherwise identical to the U.K. proposed waveform.

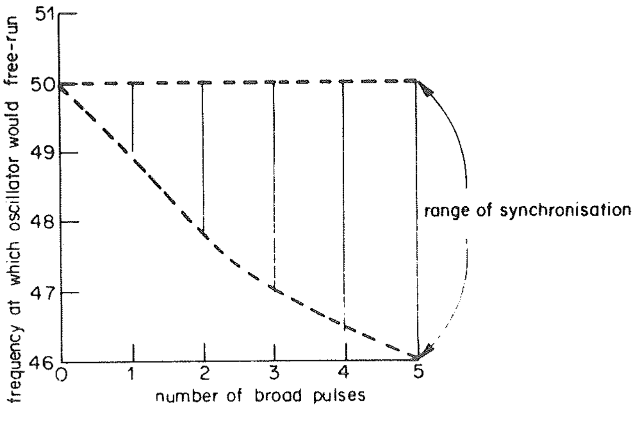

Fig. 8 - Graph showing the range of frequency settings for which synchronism was obtained as a function of the number of broad pulses (for receiver A)

4.2. Dependence of interlace upon the equalising pulses

The investigation of criterion (b) led to a great deal of work to determine the way in which domestic television receivers depend on equalising pulses in order to provide satisfactory interlace. For simplicity, the detailed description of the experimental work has been excluded from the main text, and will be found in Appendix B. However, the main conclusions will now be discussed in the light of their relevance to the proposal.

It was found that the waveform proposed by the U.K., whether it incorporated three broad-pulses as originally described, or whether it was modified to include five broad-pulses, had an unsatisfactory interlace performance on a large minority of the receivers examined. This was found to be principally due to the inherent dependence of interlace on the duration of the signal pre equalising pulse used. It was found that, for satisfactory interlace, each receiver required a different duration of pre equalising pulse, and although there were overlaps between the requirements of some receivers, no equalising pulse duration could be found which satisfied all the receivers simultaneously.

In addition, it was found that the absence of any post equalising pulses also gave rise to interlace problems in a small proportion of the receivers.

After further experiments in which the number and nature of the pre and post equalising pulses were varied, it was concluded that, with the present designs of receivers, the only simplification of the standard waveform which could be tolerated was the removal of four of the five post equalising pulses, as shown in Fig. 9(a). There is little merit in this modification, particularly as it retains the disadvantage that special signal processing is required if Sound-in-Syncs signals are to be transmitted.

5. Conclusions

It was concluded that the field synchronising waveform originally proposed by the U.K. cannot be introduced at present for the following reasons:

(1) At least one post equalising pulse in each field is necessary.
(2) Three broad pulses is not sufficient because of the reduction of vertical synchronising range which results in some cases.
(3) One pre equalising pulse in alternate fields causes interlace failure on approximately 20% of the receivers tested, the pre equalising pulse duration being 2·5μs, the theoretically-determined and experimentally-verified compromise value.

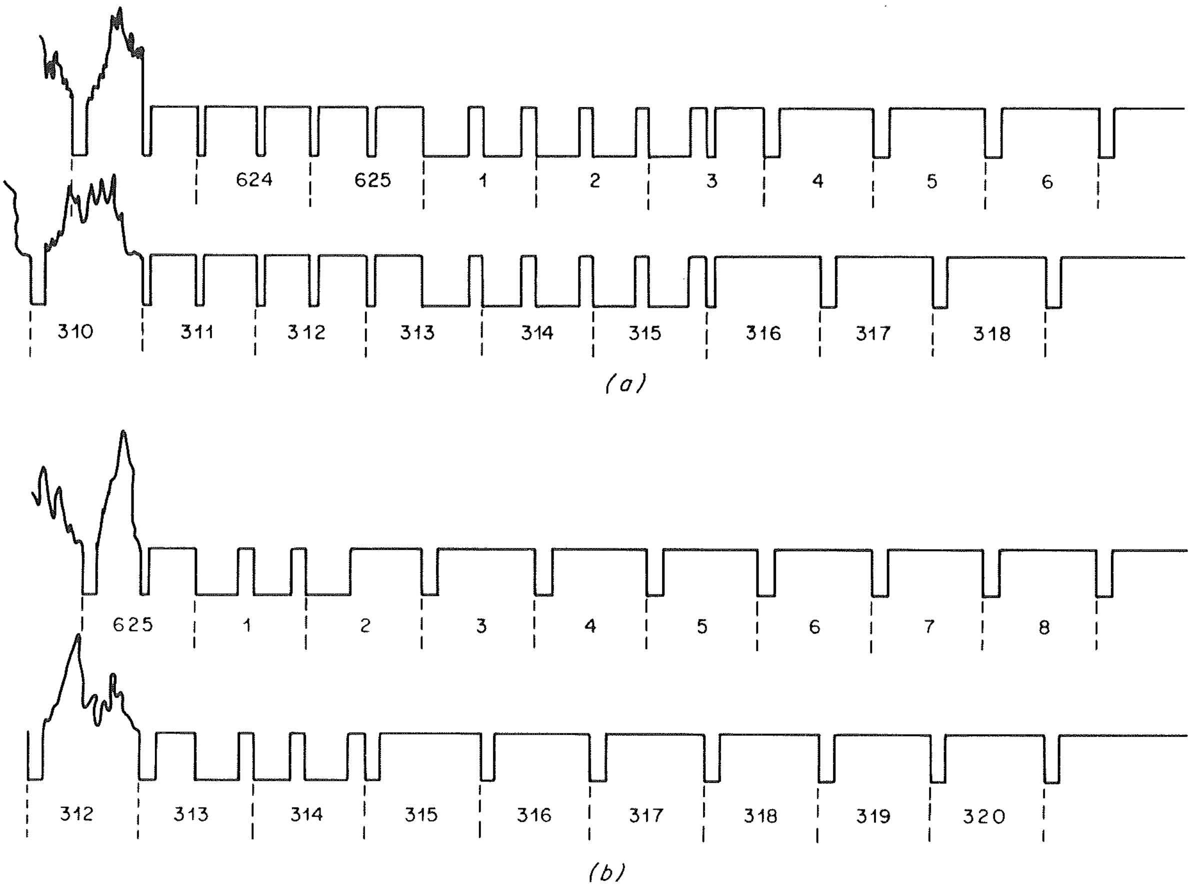

Fig. 9 - Proposals for the modifications of the field synchronising waveform
(a) Fully compatible with standard waveform *(b)* Partially compatible with standard waveform, (the original U.K. proposal)

These difficulties would not arise if the waveform in Fig. 9(a) were used but this is a proposal which offers only small advantages, particularly in view of the results of further work that has been carried out to investigate the visibility of data transmitted during the field blanking period. This work has shown that severe restrictions must be placed on the way in which data may be transmitted during the period immediately following the broad pulse sequence, as this is the interval during which television receivers carry out field flyback. Due to the absence of adequate flyback suppression in many receivers, data transmitted on lines immediately following the broad pulses becomes visible unless it is attenuated by roughly 20 dB.

In spite of the present objections to the original U.K. proposal, (illustrated in Fig. 9 (b)), it is considered worth while planning for its introduction in the future. This would be possible if receiver manufacturers were to start designing receivers capable of performing equally well on both the existing and the proposed waveforms. It is estimated* that the proportion of receivers in the hands of the public which are susceptible to the U.K. proposed waveform will have dropped from a significant value at present to an insignificant one by the end of a 15-year period.

However, the U.K. proposed waveform has a resistance to interference which is virtually the same as that of the standard waveform. It has been found, for both waveforms and for certain offsets, that interference levels no higher than −33 dB and −28 dB can be tolerated for C.W. interference and co-channel interference respectively; levels no higher than −23 dB are tolerable for the worst types of impulsive interference.

Measurements of interference susceptibility are valuable as a means of comparison between receivers, but the nature of impulsive interference is such that any attempt to compare the results of measurements carried out at different times or in different locations can be meaningless unless the means of generating it, and the nature of the measuring equipment are carefully specified.

6. Acknowledgements

The work described in this report has been carried out in liaison with Mr. H. Kitchin,** lately of the IBA, in his capacity as a joint U.K. representative at the EBU Sub-group, and with Mr. J. Baldwin of the IBA.

Thanks are due to E.R.A., Leatherhead, for their assistance in the measurement of impulsive noise sources.

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*by Brema

**The UK representatives at the Sub-Group were Mr. H. Kitchin of the IBA, and Mr. S.M. Edwardson of the BBC.

APPENDIX A

Comments on the Performance of some of the Receivers under Conditions of Severe Impulsive Interference

1. Receivers suffering clamping errors as a result of the interference.
   A, C, J, I.

2. Receivers, the line scan circuits of which were seriously disturbed by the interference.
   G, R, H, S, T, J and I (particularly severe disturbance receiver I, see photograph Fig. 3(d)).

3. Receiver F was particularly susceptible to RF radiation from neighbouring receivers.

4. Receivers N, F tended to field lock onto severe interference. See photograph Fig. 3(e).

5. Receiver R suffered field scan fold-over under conditions of severe interference.

6. Receivers which tended to be among the first ones to lose vertical synchronisation in the presence of interference.
   B, D (very frequently)
   E, F (less frequently)

7. Receivers which tended to be among the last ones to lose vertical synchronisation in the presence of interference.
   T, A (very frequently)
   C (less frequently)

APPENDIX B

Experiments to Determine the Influence of Equalising Pulses on the Interlacing Ability of Television Receivers

B.1. Theoretical Considerations

The effect of the pre equalising pulses in the standard waveform is illustrated in Fig. 1(b). If a C-R integrator is used for the separation of the field synchronising component, it is necessary to introduce equalising pulses before the broad-pulse sequence in order to allow the charge on the capacitor due to the line synchronising pulses to die away to an insignificantly low level. If this is not done, there will be a charge on the capacitor at the beginning of the broad-pulse sequence which will vary significantly from field to field because of the half-line timing difference between line synchronising pulses on alternate fields. This difference in charge will tend to cause premature triggering of the field-scan generator on alternate fields, and result in impaired interlace. The effect of the equalising pulses, therefore, is to continue to provide line synchronising information whilst at the same time causing identical charge-discharge conditions on both fields for a period of 2½ lines, a time which is assumed to be sufficient to ensure that, at the end of the equalising pulse sequence, there is little difference between the charges on alternate fields.

The effect of the equalising pulse in the proposed system is illustrated in Fig. 1(d). In this case, equality between the charges on alternate fields is obtained from the small additional charge delivered by the single equalising pulse. This additional charge clearly depends on the duration of the single equalising pulse, and the success of the proposal depends, in principle, on the choice of a suitable value for this parameter. It is evident that, in this respect, the UK proposal differs from the standard waveform since the durations of the five equalising pulses used in the latter are not critical; they serve only as a buffer between the line synchronising pulses and the broad pulses.

Theoretical analysis shows that, for perfect equalisation of charge, the width of the single pre equalising pulse in the UK proposal is a function of the time-constant of the C-R integrator used on the receiver, and this theoretical relationship is plotted in Fig. 10. For the present, attention is drawn only to the curve and the vertical lines should be ignored. The curve shows that for time-constants greater than or equal to 100 μs, the optimum equalising

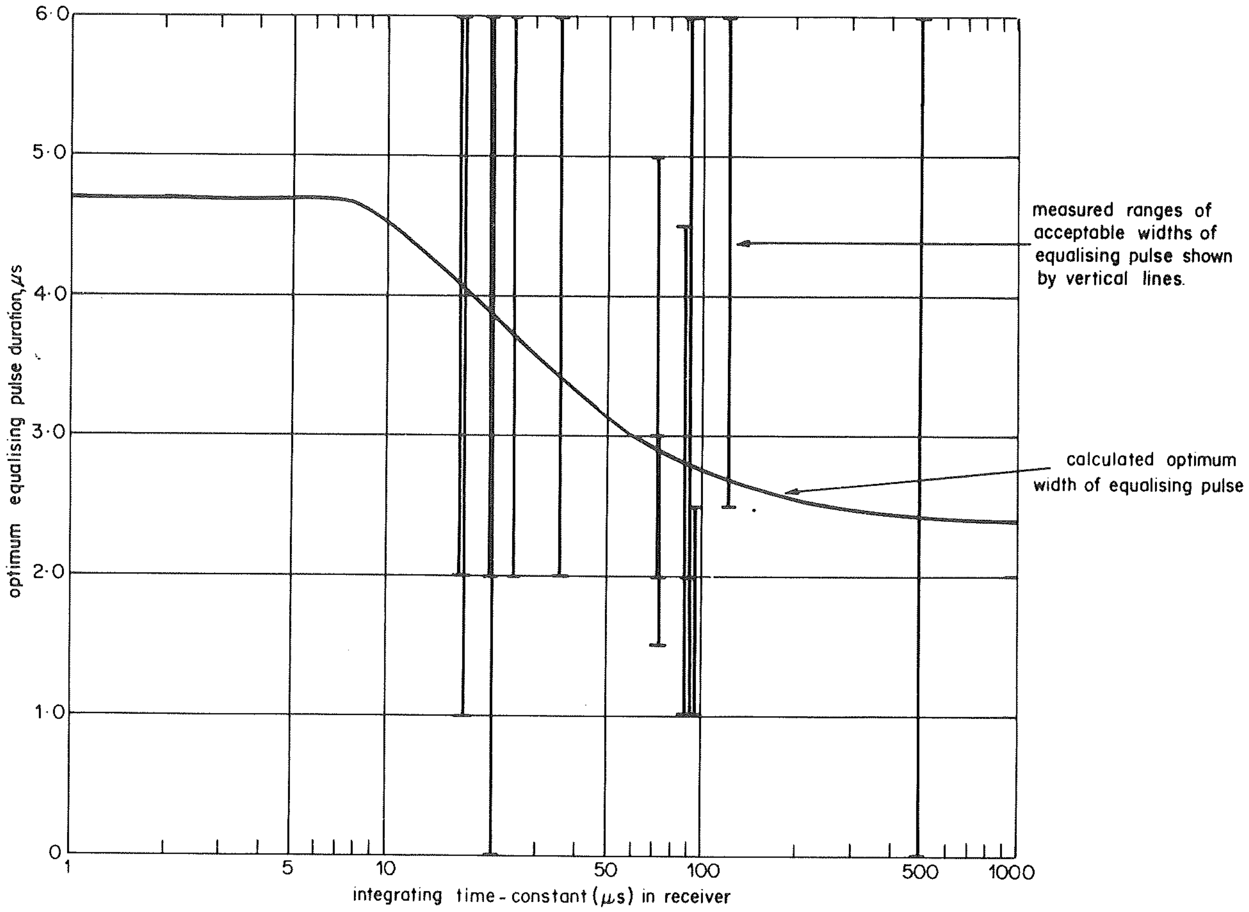

Fig. 10 - Optimum equalising pulse width as a function of the time-constant of an R-C integrator

pulse duration remains more or less constant at ~ 2·5 μS. It was on the assumption that the time-constants used in receivers were equal to or greater than 100 μS that the UK proposal was formulated.

B.2. Experimental determination of optimum pre equaequalising pulse duration

An investigation was carried out into the optimum duration of the single pre equalising pulse for each receiver used in the interference tests using the UK proposal (modified to include five broad-pulses); it was possible to switch instantaneously between the modified UK proposal, and the standard waveform. This enabled the interlace performance obtained using the two systems to be compared. Certain of the receivers had a somewhat poor interlace performance, even with the standard field synchronising waveform. In these cases the vertical-hold control was adjusted to give the best possible interlace field using the standard waveform, and the resulting performance was taken as the norm for that receiver. The tests consisted of noting the interlace performance using the standard waveform and then switching over to the modified UK proposed waveform and adjusting the duration of the equalising pulse for the same quality of interlace. In practice, it was found that there was, for each receiver, a range of pre equalising pulse duration for which the interlace was substantially the same as that obtained with standard synchronising signals. These ranges of acceptable equalising pulse duration are plotted in Fig. 11 from which it will be seen that there is no common area of overlap, and hence no generally acceptable duration of single pre equalising pulse; indeed, one receiver (Receiver M) would not interlace satisfactorily at all.

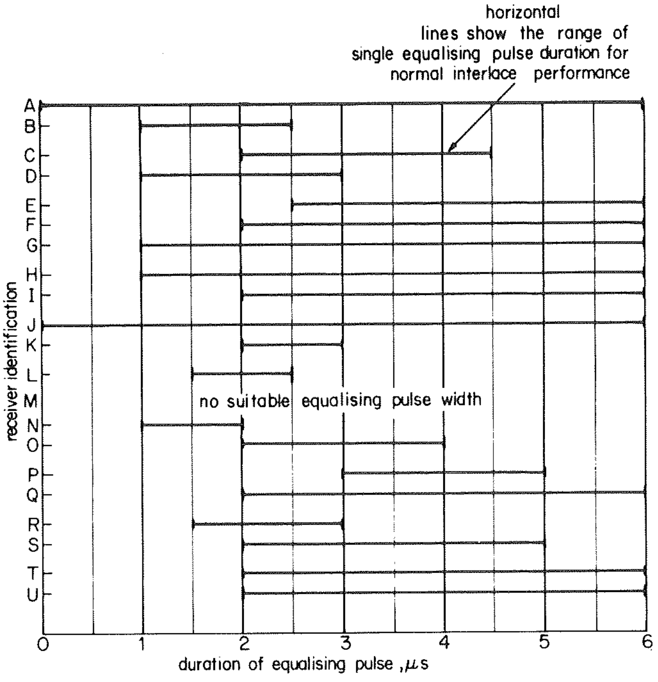

Fig. 11 - Range of equalising pulse widths for which satisfactory interlace was obtained

This unsatisfactory performance of the UK proposal which specifies a pulse duration of 2·5 μS was thought to be due to one or both of two causes.

(1) The possibility that the C-R integrators in the receivers had time constants less than about 100 μS, thereby requiring equalising pulse duration different from 2·5 μS.

(2) The absence of post equalising pulses in the UK proposal.

The first possible cause was further investigated by extracting the time-constants of the C-R integrators from the circuit diagrams of the receivers. This was not straightforward since some circuits use the impedance of active components such as valves or transistors as a part of the integrator and this can sometimes result in different effective time-constants during the charging and discharging operations. Nevertheless, where possible, representative time-constants were extracted and these, together with the corresponding measured ranges of acceptable equalising pulse duration, are plotted in Fig. 10. The majority of the receivers had time constants less than 100 μS and hence it was not possible to choose a value of equalising pulse duration suitable for all the receivers. It appears that receivers are currently being manufactured with C-R time constants anywhere in the range from 5 μS to 5 ms. This however, does not provide a complete explaination of why there is such a wide divergence in the ranges of acceptable pre equalising pulse duration. In Fig. 10 the range of acceptable pulse duration for one receiver is not cut by the theoretical curve; also, as was previously pointed out, one receiver failed to interlace at all, irrespective of the duration of the equalising pulse.

B.3. The importance of post equalising pulses

A number of experiments were then carried out to assess the importance of post equalising pulses (which were not included in the UK proposal).

The purpose of post equalising pulses is to maintain identical charge conditions on alternate fields for 2½ lines after the last broad pulse, since there is a possibility that some field-scan generators might continue to be sensitive to the synchronising waveform for a short time after they have been triggered. Thus, protection is provided against dissimilar effects on alternate fields which might be visible as impaired interlace. Fig. 12(a) illustrates the charge-discharge conditions encountered during and immediately after the broad-pulse sequence contained in the UK proposal. The inequality between the fields is apparent as soon as the broad-pulse sequence ends. Fig. 12(b) illustrates a modification, which was then tested, in which a single equalising pulse of duration 2·35 μS was added on alternate fields, together with a single pre equalising pulse of experimentally determined optimum duration. This produces a characteristic which although not identical on both fields, is less dissimilar, and integrates over each field to a constant value. The effect of adding this single post-equalising pulse was negligible for the majority of receivers; however, two of the receivers were significantly affected. Receiver M, which had previously re-

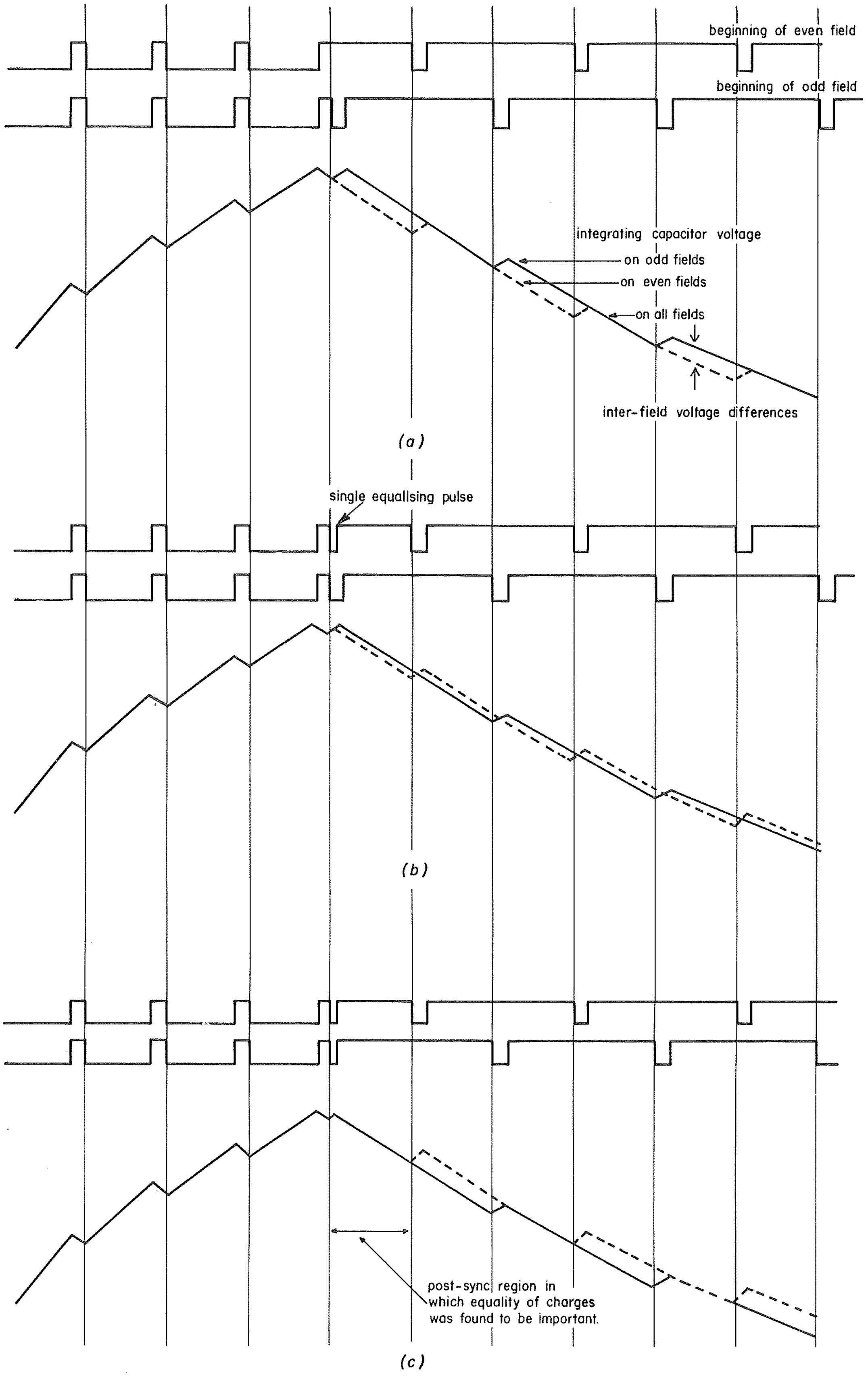
beginning of even field
beginning of odd field
integrating capacitor voltage
on odd fields
on even fields
on all fields
inter-field voltage differences
(a)
single equalising pulse
(b)
post-sync region in which equality of charges was found to be important.
(c)

Fig. 12 - (a) The voltage on the capacitor of an R-C integrator with no post-equalising pulse (b) The voltage on the capacitor of an R-C integrator with one post-equalising pulse on alternate fields (c) The voltage on the capacitor of an R-C integrator with one post-equalising pulse on each field.

fused to interlace now interlaced satisfactorily over a range of pre equalising pulse duration from 1 μS to 3 μS. However, the interlace performance of receiver B was noticeably impaired so as to be almost unacceptable. It was clear therefore that the addition of a single post equalising pulse, in the form envisaged, was not a solution to the problem.

An effort was then made to isolate the effects on the receivers due to post equalising pulses. In this experiment, all five normal pre equalising pulses were included, and the post equalising pulses could be removed one at a time until, ultimately, there were none at all. The majority of receivers gave a satisfactory performance even with no post equalising pulses, but under these conditions three receivers M, D and P, showed a marked degree of 'pairing' which disappeared when one post equalising pulse was added; this one post equalising pulse was added on both fields and is illustrated in Fig. 12(c). It has the effect of equalising the C-R charge characteristic for half a line period following the broad-pulse sequence, and this appeared to satisfy all the receivers.

B.4. Experiment to determine the minimum number of pre equalising pulses that need to be used

The excessive sensitivity of the receivers to the duration of the single pre equalising pulse in the UK proposal made it necessary to consider further modifications to that proposal. It was felt that a compromise solution might be found by using waveforms of the type illustrated in Fig. 13. Fig. 13(1) shows the waveform with a single pre equalising pulse as defined by the UK proposal. Fig. 13(6) shows the standard field synchronising waveform (ignoring the equalising pulse shown dotted). Fig. 13 (2), (3), (4) and (5) show the progressive addition of one equalising pulse in each field so as to form a gradual transition between waveforms (1) and (6). In theory, any of the waveforms should provide correct interlace, but with a decreasing dependence on the duration of the added equalising pulse (marked in each case by an arrow), as a result of the buffering action of the intermediate equalising pulses. The duration of the added pulse would have to be zero in order to make waveform (6) identical to the existing standard; the extra pulse is shown in broken lines in this case. An experiment was carried out to determine the interlace performance of each receiver as a function of the duration of the additional pre equalising pulse, for each of waveforms (1) to (5). During this experiment there were five post equalising pulses at all times.

The results are plotted in Fig. 14 which shows the ranges of acceptable duration of additional pre equalising pulse for each of the receivers, and each of the waveforms (1) (2) (3) (4) and (5). The results of this experiment were somewhat unexpected. Some of the results (for example those for receivers S, N, L and R) showed

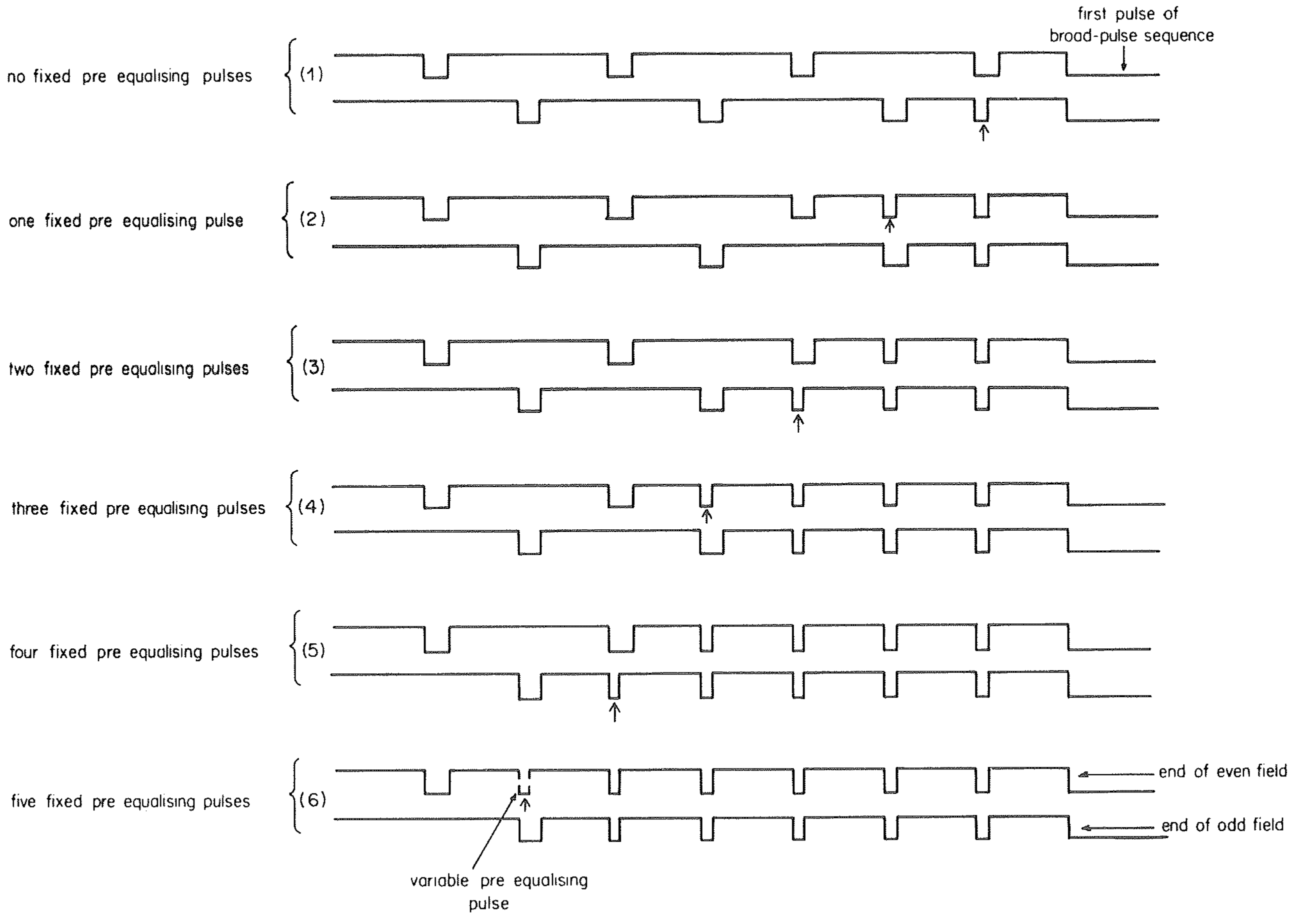
first pulse of broad-pulse sequence
no fixed pre equalising pulses
(1)
one fixed pre equalising pulse
(2)
two fixed pre equalising pulses
(3)
three fixed pre equalising pulses
(4)
four fixed pre equalising pulses
(5)
five fixed pre equalising pulses
(6)
end of even field
end of odd field
variable pre equalising pulse

Fig. 13 - Diagram showing how equalising pulses can be added to form a gradual transition from the proposed to the standard field synchronising waveform

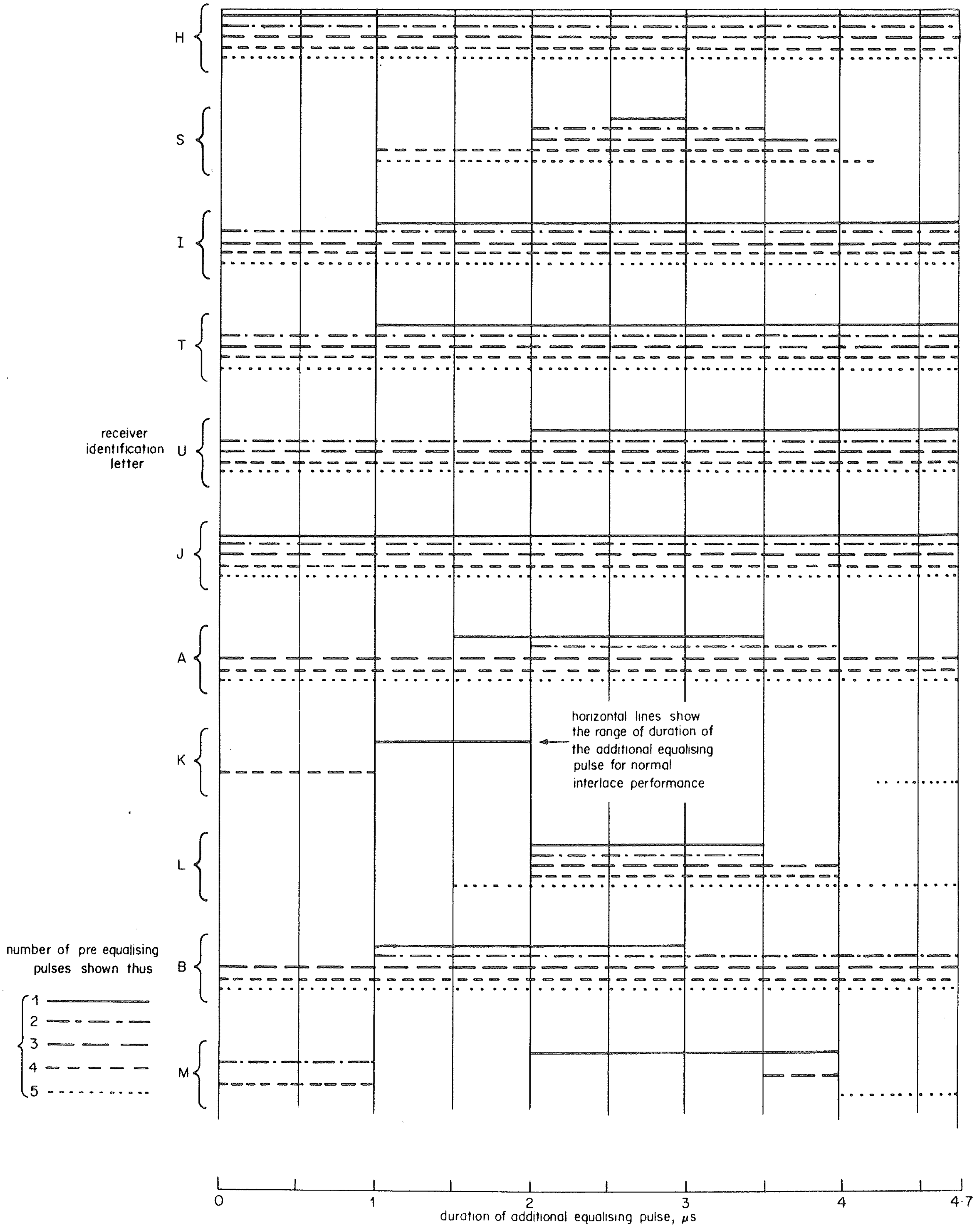
H
S
I
T
U
J
A
K
L
B
M
receiver identification letter
horizontal lines show the range of duration of the additional equalising pulse for normal interlace performance
number of pre equalising pulses shown thus
1
2
3
4
5
0
1
2
3
4
4·7
duration of additional equalising pulse, μs

Fig. 14

Fig. 14 cont.

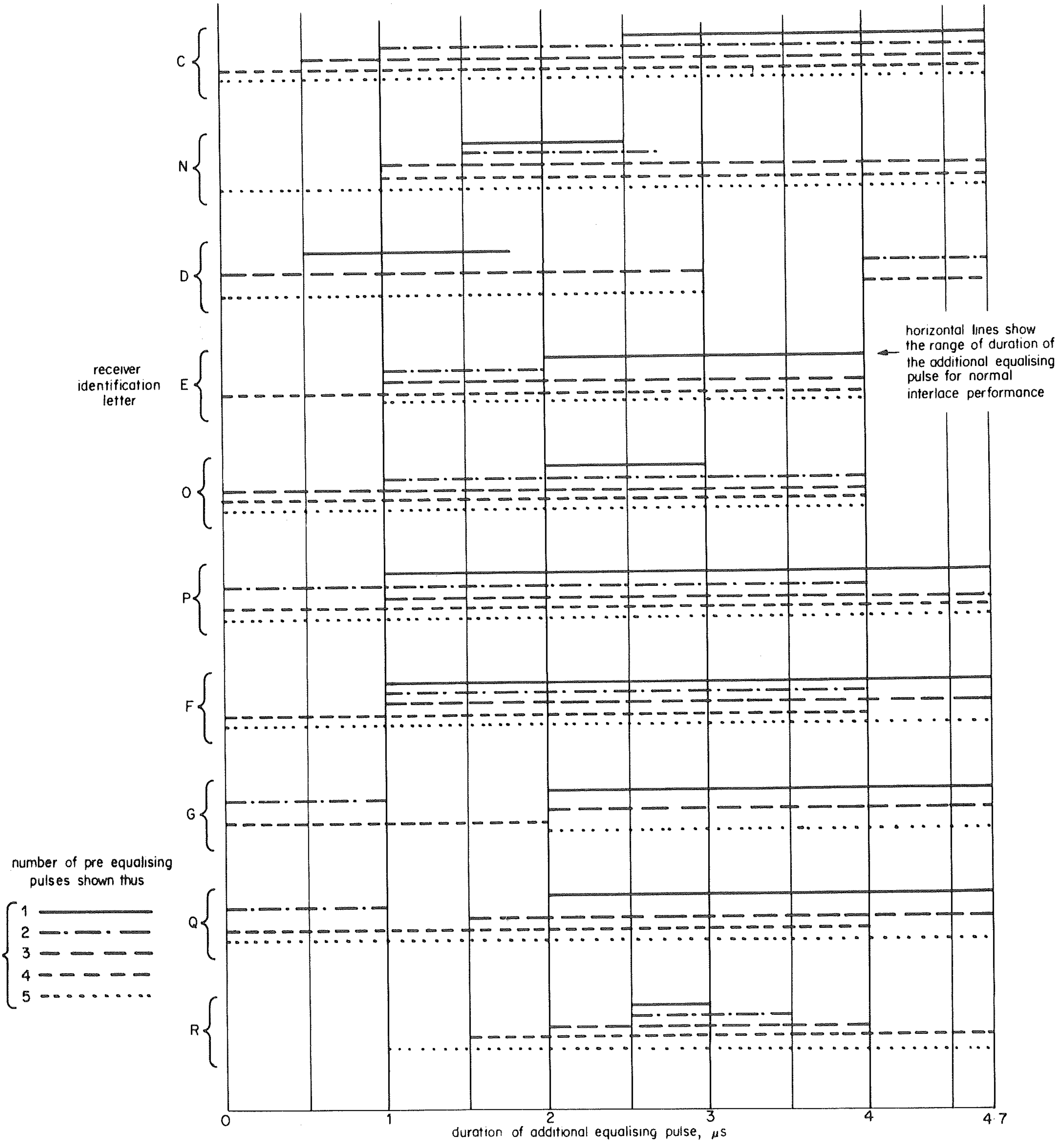

Fig. 14 - Ranges of acceptable additional equalising pulse widths as a function of the number of pre-equalising pulses in the waveform

the expected trend whereby, as the number of pre-equalising pulses is increased, the system shows less sensitivity to variations in the duration of the additional pre equalising pulse. However for a large number of receivers, for example receivers K, M, D, F, G and Q, there was a tendency for the ranges to fall into two distinct groups consisting of those preferring an even number of pre equalising pulses and those preferring an odd number.

B.5. Discussion of Results

An explaination of these unexpected results can perhaps be found with the aid of the graph in Fig. 15. This graph is derived from theory and is a plot of the difference between the voltage appearing across the integrating-capacitor at the beginning of the broad-pulse sequence of one field and the corresponding voltage on the next field* (for an input synchronising waveform of one volt), as a function of the number of non-variable pre equalising pulses. The number of pre equalising pulses is assumed to be equal on both fields; hence for five equalising pulses the graph represents the situation on the standard waveform.

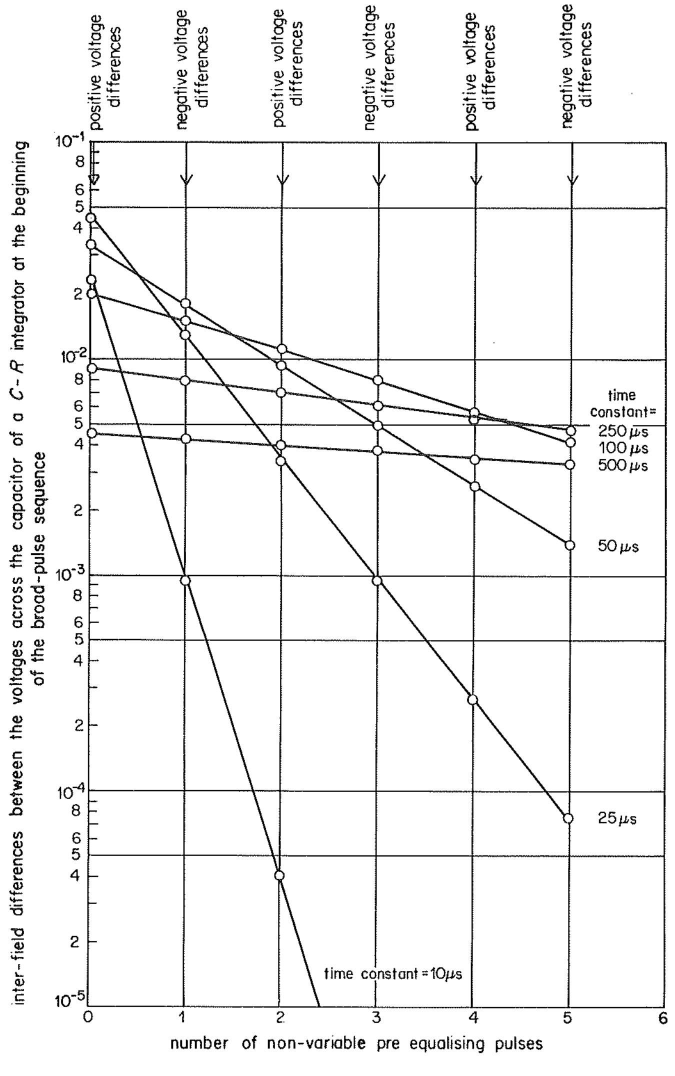

Fig. 15 - Voltage difference across capacitor at beginning of broad pulse sequence as a function of the number of pre-equalising pulses

Attention is especially drawn to the inter-field voltage differences when five pre equalising pulses are used, and when no pre equalising pulses are used. It will be recalled that the purpose of five equalising pulses in the present system is to provide a buffer-period during which the inter-field voltage differences can decay to an insignificant level. This is seen, from the graph, to occur most effectively for short C-R time constants. For larger time constants, say greater than 100 μS, the voltage difference after five equalising pulses is only slightly less, and in any case of the same order of magnitude as for no equalising pulses; hence there follows the interesting conclusion that receivers whose C-R time constants are greater than about 100 μS cannot derive much benefit from the pre equalising pulses at present transmitted. It follows that in order to achieve interlace with a simple C-R circuit, many receivers must have built-in compensation for inter-field voltage differences. This might be achieved for example, by intentional (or accidental) coupling from the horizontal-scan circuits into the vertical-scan circuits.

It will further be noted from the graph that the voltage differences alternate in polarity** as the number of equalising pulses is increased or decreased. Even numbers of equalising pulses give rise to positive voltage differences, odd numbers give rise to negative voltage differences. Hence, a typical receiver designed to operate on five pre equalising pulses would contain positive compensation for this inter-field voltage difference. If four equalising pulses were then used, the compensation would add to the inter-field voltage difference and increase the error. This is thought to be a possible reason for the curious grouping of the results illustrated in Fig. 14 into two groups preferring odd and even number of pre-equalising pulses respectively, and is evidence which corroborates the view that receivers with C-R time constants greater than 100 μS have built in interlace compensation.

The explanation just given has, for the sake of simplicity, made certain assumptions which are justifiable to the extent that they facilitate a qualitative understanding of the problem. First, it has been implied that the degree of interlace pairing is determined by the absolute inter-field voltage differences. It should, however, be borne in mind that as the time constant of the C-R circuit is varied, the level of the separated field synchronising pulse also varies, and each receiver will therefore contain any adjustment of gain necessary to compensate for this. It is a closer approximation to the truth to say that interlace pairing depends on the inter-field voltage differences relative to the gain. However, over the range of C-R time constants constants under consideration (10 μS to 500 μS) it has been calculated that the ratio of variations in separated field synchronising pulse level is approximately 5:1, much less than the corresponding ratio of changes in inter-field voltage difference, deduceable from Fig. 15. Thus the substance of the preceding argument is unchanged.

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*This will subsequently be referred to as the 'inter-field voltage difference'.

**The sign convention chosen in Fig. 15, and subsequently used in the text to illustrate the alternating polarity of inter-field voltage differences, is arbitrary and does not affect the logic of the ensuing argument.

A further point which must be considered is that interlace pairing is a manifestation of inter-field timing differences and is only indirectly brought about by inter-field voltage differences. The relationship between the two will depend on the shape of the charge characteristic of the C-R circuit, and also the level at which limiting of the output from the charge-discharge circuit takes place.

This means in general that interlace errors will be more exaggerated on long time-constant circuits whose charge characteristics will have a smaller mean slope. Again, however, the substance of the preceding argument is not affected by this qualification.

In the light of these experiments, it seems most unlikely that the five pre equalising pulses can be changed in any way without incurring some loss of compatibility with the existing system. The only modification to the existing waveform which was tolerated by all the receivers tested was the removal of four of the five post equalising pulses. This is therefore the only recommendation which can be made if complete compatability with the exisitng receivers is vital. This proposal is illustrated in Fig. 9(a); it has no special merit because the television lines which appears to release for other uses occur at the same time as the vertical retrace or flyback of television receivers and it shares with the standard waveform the disadvantage that special processing is required if Sound-in-Syncs signals are to be transmitted.

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